REMEDIAL INVESTIGATION REPORT
FOR HIGH PRIORITY SITES
(881 HILLSIDE AREA)

VOLUME II

(APPENDICES A,B, AND C)

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN,COLORADO
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ROCKWELL INTERNATIONAL
NORTH AMERICAN SPACE OPERATIONS
ROCKY FLATS PLANT

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ADMINISTRATION CONTRACT DE-AC04-76DPO3533

NOTICE

All drawings located at the end of the document.

APPENDIX A

REPORT OF GEOPHYSICAL INVESTIGATIONS
881 HILLSIDE AREA
ROCKY FLATS PLANT
GOLDEN, COLORADO

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SECTION 1

INTRODUCTION

Geophysical surveys of the 881 Hillside area of the Rocky Flats Plant, Jefferson County, Colorado, have been completed as specified in the CEARP IGMP/SSMP Sampling Plan, dated February 1987, for the facility. The surveys were completed as part of the CEARP investigations of high priority sites at the Rocky Flats Plant.

The purpose of the geophysical surveys was to attempt to identify the location of known SWMUs or other potential sources, and/or plumes of environmental contaminants, by locating areas of high or low responses (anomalies) on various geophysical instruments. Once anomalies have been identified, borings and monitoring wells will be located to verify the significance of these anomalous areas as part of the overall site investigation program. In addition, electrical resistivity was used to provide information about site stratigraphy. Stratigraphic information was obtained by performing vertical electrical soundings (VES) at various locations across the site.

SECTION 2

SITE BACKGROUND

Information available at the time that the geophysical surveys were done indicate that surficial materials at the 881 Hillside area consist of Rocky Flats Alluvium, colluvium, and valley fill alluvium. The Rocky Flats Alluvium beneath the land surface (at and north of Building 881) varies in thickness from 4 to 14 feet. The Rocky Flats Alluvium is a poorly sorted deposit of sand, gravel, and cobbles that contains some clay horizons. The 881 Hillside itself is mantled with slopewash material (colluvium) consisting of 2 to 5 feet of sandy clay underlain by 4 to 5 feet of sandy gravel. The materials underlying the slope merge downhill with the valley fill alluvium. The valley fill alluvium consists of thin (3 to 8 feet thick) sandy gravels. Bedrock beneath the 881 Hillside area at monitoring well 59-86 consists of approximately 10 feet of claystone underlain by 7 to 12 feet of sandstone. The sandstone is in turn underlain by additional claystone. These claystones and sandstones dip approximately 15 to 30° to the east (DOE, 1986f), as discussed in the main body of the report.

The hydrogeology of the 881 Hillside area appears to be dominated by flow from the Rocky Flats Alluvium, through the colluvium, and into the valley fill alluvium. The flow system is complicated by apparently unsaturated portions of the Rocky Flats Alluvium both west and east of Building 881. Groundwater occurs in the sandy gravel of the slopewash material and in the sandstone bedrock. The static water level in the sandstone appears to be about 18 feet lower than in the slopewash, based on water levels in 59-86 and 69-86.

Results of groundwater sampling (DOE, 1986f) indicate that groundwater in both bedrock and surficial materials is of poorer quality than the upgradient groundwater in the Rocky Flats Alluvium. The groundwater at the 881 Hillside area apparently contains more sodium (as a percentage of major ions) than upgradient alluvial waters and has total dissolved solids (TDS) concentrations in the range of 1000 milligrams per liter (mg/l). Upgradient alluvial groundwaters have TDS concentrations of approximately 100 to 200 mg/l. Radioactive constituent values are approximately equal to upgradient values, and dissolved metal concentrations are generally similar. However, strontium metal concentrations are higher at the 881 Hillside area than at upgradient locations. Volatile organic compounds (VOCs) were detected in only one area of the 881 Hillside area. Significant concentrations (greater than 1000 parts per billion) of 1,1-dichloroethylene (1,1, DCE), 1,1,1-trichloroethane (1,1,1 TCA), trichloroethylene (TCE), and tetrachloroethylene (PCE) were detected in well 9-74 during 1986.

The 881 Hillside location has been the site of various spills and disposal operations during the history of the plant. The ten solid waste management units (SWMUs) that make up the 881 Hillside area are described below and shown on Figure 1.

- Oil Sludge Pit (SWMU Ref. No. 102) - In 1958, approximately 30 to 50 drums of oil sludge from cleaning storage tanks were emptied into a pit south of Building 991 and covered with soil.

- Chemical Burial (SWMU Ref. No. 103) - An area south of Building 881 was reportedly used to bury unknown chemicals.

- Liquid Dumping (SWMU Ref. No. 104) - Prior to 1969, the area east of Building 881 was reportedly used for dumping liquid and disposing of empty drums. The types of liquids and residual materials in the drums is unknown.

- Out-of-Service Fuel Tanks (SWMU Ref. No. 105) - Asbestos was reportedly placed in two out-of-service No. 6 fuel oil tanks located south of Building 881. The tanks were then filled with concrete.

- Outfall (SWMU Ref. No. 106) - An outfall south of Building 881 may discharge on an occasional basis. The outfall is apparently a cleanout pipe for an overflow line from a cooling tower.

- Hillside Oil Leak (SWMU Ref. No. 107) - In 1973, No. 6 fuel oil from an undetermined source was observed on the hillside south of Building 881. Straw was used to limit the spread of the oil. The oil-soaked straw and soil were removed and placed in the present landfill.

- Multiple Solvent Spills (SWMU Ref. No. 119) - In 1967, two areas east of Building 881 and along the southern perimeter road were used as solvent storage facilities. Minor leaks and spills may have occurred in these areas. The facilities were removed by April 1972.

- Radioactive Site - 800 Area Site #1 (SWMU Ref. No. 130) - An area east of Building 881 was used for the disposal of 320 tons of plutonium-contaminated soil (about 7 dpm/g alpha activity) from the Building 776 fire. The area was also used for the disposal of approximately 60 cubic yards of plutonium-contaminated soil (about 250 dpm/g alpha activity) from Building 774 waste storage tank area. Site #1 was covered with about 1 to 2 feet of soil.

- Sanitary Waste Line Leak (SWMU Ref. No. 145) - In January 1981, the sanitary waste line located south of Building 881 leaked. An earthen dike was constructed to prevent runoff into the south interceptor ditch and the line was repaired. The sanitary waste line carried radioactive laundry effluent from about 1969 to 1973. Whether other hazardous materials have ever been carried in the line is unknown.

- Building 885 Drum Storage Area (SWMU Ref. No. 177) - The Building 885 Drum Storage Area will be closed under Interim Status (40 CFR 265). Complete information on this solid waste management unit is provided in the Interim Status closure plan.

SECTION 3

METHODS

3.1 GRID SURVEY

A grid system was established on the 881 Hillside area in order to provide lateral control of measurement location. Survey stations were staked at 60-foot intervals and marked with a coordinate designation based on the Rocky Flats Plant grid system. All geophysical survey points were located based on this coordinate system.

3.2 ELECTROMAGNETIC CONDUCTIVITY

Electromagnetic conductivity (EM) surveys of the 881 Hillside area of Rocky Flats Plant were conducted using both EM-34-3 and EM-31 Terrain Conductivity Meters manufactured by Geonics, Ltd. Electromagnetic techniques of measuring terrain conductivity operate by imparting an alternating current to a transmitter coil. Current passing through the transmitter coil produces a magnetic field which in turn induces small currents in the underlying strata. Currents within the geologic materials produce a secondary magnetic field which is sensed by the receiver coil. It has been shown that under certain constraints, the ratio of the secondary to the primary magnetic field is proportional to terrain conductivity (Geonics, 1980). This fact allows conductivity to be read directly from the instrument in units of millimhos per meter (mmhos/m).

The EM-34-3 unit measures the average conductivity of materials between two hand-held coils spaced 10, 20 or 40 meters apart. The effective depth of penetration is variable by altering intercoil spacing and coil orientation. EM-34-3 conductivity was measured at 253 survey stations, in both horizontal and vertical dipole configurations, with a coil separation of 10 meters. Measurements taken in the horizontal dipole mode yielded an effective depth of exploration of 7.5 meters with the largest signal contribution from near-surface materials. Vertical dipole measurements yielded an effective depth of exploration of 15 meters with a smaller signal contribution from near-surface materials. The survey was run on a 60-foot grid system across the site. This spacing was chosen to allow nearly continuous conductivity data to be obtained along the survey lines.

The EM-31 unit measures the average conductivity of materials between two fixed coils spaced 3.7 meters apart. This configuration yields an effective depth of exploration of 6 meters. The survey was conducted at 15-foot intervals along east-west oriented survey lines. Survey lines were spaced at 30-foot intervals, except where examination of the data showed that additional data collection would aid in the definition of anomalous areas. A total of 2,172 data points were collected with the EM-31.

Both EM-34-3 and EM-31 were utilized to characterize the site because of the characteristic differences between the two instruments. The EM-34-3 is best suited to screen broad areas of a site for changes in conductivity. The EM-34-3 is less sensitive to small conductors, such as single drums or small pits, than is the EM-31 because of its relatively large coil spacing. However, the EM-34-3 is capable of surveying to a greater depth and is less sensitive to surficial materials (soils) in the vertical dipole configuration than is the EM-31. This gives the EM-34-3 the capability of identifying contaminant plumes, more readily than the EM-31, in areas where there is sufficient conductivity contrast.

3.3 RESISTIVITY

Nine vertical electrical soundings (VES) surveys were completed at the 881 Hillside area. VES-1 was completed north of the north ridge as a background survey point. VES-2 and VES-3 were completed on electromagnetic conductivity anomalies at the east end of the site and near the east end of SWMU 119.2, respectively. VES-4 and VES-6 were completed at electromagnetic conductivity and magnetic anomalies near monitoring wells 59-86, 60-86, and 69-86. VES-7 was located immediately south of the security fence, south of Building 881, as a background survey for the southwestern corner of the 881 Hillside area. VES-5 and VES-8 were also completed at electromagnetic conductivity and magnetic anomalies at the southwestern corner of the area. VES-9 was completed at the reported location of SWMU 104. The locations of the VES points are presented below and shown on Figure 2.

LOCATION OF VES POINTS

Sounding No.	Rocky Flats Plant Grid System Coordinates	
1	N-35420	E-21520
2	N-35420	E-22030
3	N-35060	E-21760
4	N-34790	E-21190
5	N-34760	E-20710
6	N-34820	E-21100
7	N-35000	E-20740
8	N-34735	E-20650
9	N-35330	E-21160

All of the VES surveys were made using a Bison Model 2390 transmitter and receiver. This system is a microprocessor controlled signal enhancement unit with automatic self potential removal and current control. The unit displays the reading in the form of millivolts. The Bison offset sounding cable system (BOSS Model 2365) and steel stake electrodes were used for all VES surveys.

Electrical resistivity measures the electrical resistivity of the soil by passing an electrical current into the ground from a pair of electrodes and measuring the electrical voltage with a second pair of electrodes. Resistivity data is generally recorded as apparent resistivity, ρ_a, which can be found from the equation: $\rho_a = K \times V/I$; where V is the observed voltage, I is the injected current, and K is the geometric shape factor. The basic unit of resistivity measurement and apparent resistivity is the ohm-meter. K is a shape function of the geometry of the electrode arrangement typically called an array.

The Wenner array is the most commonly used array for hydrogeologic studies. The Wenner array was selected for its ease of field operation and data analysis, and its sensitivity to soil resistivity changes caused by variation in moisture content. Its main advantages are that it has a much lower sensitivity to geologic noise and localized changes in soil resistivity unrelated to large-scale features of interest, and it returns a relatively high voltage for a small transmitter current allowing the use of smaller transmitters. Its major disadvantage lies in having a somewhat lower vertical resolution and much lower horizontal resolution than other arrays. For the Wenner array, the geometric shape factor is given by $K=2\pi a$, where a is the spacing between electrodes.

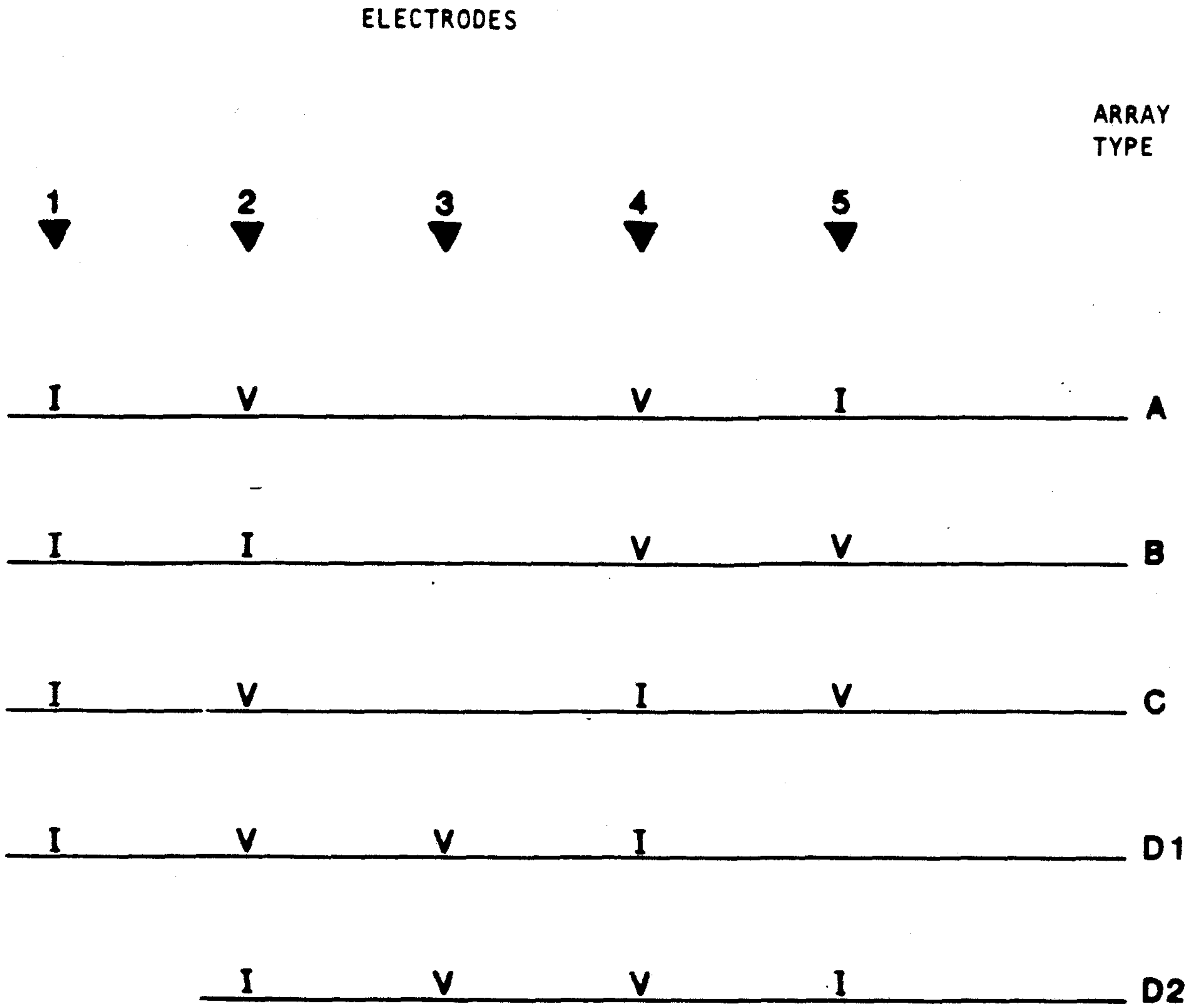
The apparent resistivity reading is not indicative of the resistivity at any single depth but is an average of soil resistivity over a range of depths. The depth of exploration is proportional to the a-spacing used with the principal response coming from a depth of about 1/3 to 1/2 of the a-spacing. VES surveys are conducted by making a series of measurements starting with a small a-spacing, usually less than 1 meter, and increasing the spacings logarithmically out to several tens or even hundreds of meters.

The BOSS system utilizes an array of cables designed to allow completion of Wenner soundings very quickly. The manufacturer, Bison Instruments, Inc., indicates that significant reductions in the effects of geologic noise should result. The cables have electrode takeouts in a geometric series with the a-spacing increasing by a factor of two. Five different array measurements are made at each a-spacing as shown on Figure 3. Measurements D-1 and D-2 consist of a pair of overlapping or "offset" Wenner arrays. If the local stratigraphy consists of a series of flat layers, both arrays D-1 and D-2 will give the same approximate apparent resistivities. Millivolt values from the five array measurements at each a-spacing are used to calculate a single Wenner resistivity reading.

3.4 MAGNETOMETRY

Thirty-four magnetic survey lines were completed at the 881 Hillside area. The earth's total magnetic field intensity was measured at 1,585 survey stations. The survey was conducted using an EG&G Geometrics Memory Proton Precession Magnetometer, Model G-856X, with a gradiometer option.

The magnetic method used to measure the earth's total magnetic field intensity temporarily polarizes spinning hydrocarbon protons in the magnetometer sensor. The temporary polarization is obtained through the amplification of a uniform magnetic field generated by a current passing through a coil of wire. When the current is removed, the spin of the protons causes them to revolve in the direction of the earth's magnetic field. The spinning protons then generate a small signal in the same coil used to polarize them. This signal is directly proportional to the magnetic field intensity by



LEGEND

I Electrodes used as a transmitter.

V Electrodes used as a receiver.

6 007 87	Chen & Associates	ARRAY TYPES USED IN BOSS SYSTEMS FOR VES SURVEYS	Fig. 3

the proportionality constant known as the gyromagnetic ratio. The precessional frequency is then measured by a digital counter as the absolute value of the earth's magnetic field intensity with an accuracy of 0.1 gammas.

The presence of metallic items in the near surface creates magnetic anomalies in the earth's magnetic field. The location and sensitivity of the magnetic sensors becomes paramount for detection of these metallic items. If the sensor is placed too close to the items, the magnetic anomaly may overwhelm the ability of the sensor to obtain a reading. By the same logic, if the sensor is too far away, the magnetic anomaly may not be large enough to affect the sensor.

The magnetometer used was equipped with a gradiometer option allowing two field readings at different heights and a gradient reading based on the two readings obtained. The unit makes a measurement of the earth's total magnetic field intensity and displays the result to an accuracy of 0.1 gammas. The reading is automatically stored along with the day, time of day, line number, and reading number in the digital memory. The data are then retrieved at the end of the day by transferring them to a computer through the computer's communications port.

The magnetic survey was conducted on a grid with a north-south spacing of 30 feet and an east-west spacing of 15 feet. Prior to beginning the survey, a base station point was established in an area with no known underground or overhead obstructions. Each day of the magnetic survey began and ended with a base station reading for use in removal of diurnal variations. Every 45 to 60 minutes during the survey, a base reading was also obtained for removal of diurnal variations throughout the survey day.

3.5 METAL DETECTOR

Metal detector surveys were conducted at locations of interest at the 881 Hillside area, including conductivity and magnetic anomalies, the reported locations of SWMUs, and cultural features such as buried pipelines or cables. The primary purpose of the survey was to define the areal extent of metallic cultural features such as Western Slope Gas Company's underground natural gas lines and the outfall pipelines at SWMU 106 and 107. The surveys were also to define, if possible, the presence of metallic items at conductivity and magnetic anomalies. A White's Treasuremaster TM600 Series 2 metal detector was used to conduct the survey.

A metal detector operates on a principle similar to a magnetometer. Both instruments measure the earth's magnetic field intensity with the principal difference being that the metal detector is adjusted to be in-phase with remnant magnetization present in the earth's magnetic field. Any magnetic anomaly with sufficient amplitude to create an out-of-phase response in the metal detector is detected. The in-phase adjustment allows the instrument to look at coarse measurements of the earth's magnetic field typically on the order of 10,000 gammas. Due to the nearness of the sensor to the items in question, significant changes in the magnetic field intensity can be sensed. Metal detectors are used exclusively to locate buried underground utilities and metallic items. They are not used to define subsurface conditions as magnetometers are used.

The TM600 is a two-coil unit with electronic nulling controls, sensitivity controls and a ground reject control. The ground reject control allows the unit to automatically adjust to eliminate false responses due to changing ground conditions, primarily from the mineral magnetite and its associated minerals. A multi-purpose, sensitivity meter is used to monitor the received target signals and a built-in speaker produces a tone which is proportional to the signal received.

Once an area of interest was identified, a grid with nodes spaced on the order of 5 to 10 feet was identified over the area. Two passes were made over the area in question at 90^{o} to one another. This resulted in pinpointing the item in question and aided in defining the areal extent. Upon location of the item, a pin flag was placed to mark the areal extent in the field of the signal from the metal detector. These areas were marked as areas to be avoided during subsequent intrusive activities (e.g., drilling).

SECTION 4

DATA REDUCTION

4.1 ELECTROMAGNETIC CONDUCTIVITY

Conductivity and magnetometry data were processed on WESTON's Univac 1160 mainframe, Tektronix 4014 terminal and Tektronix 4663 plotter, with a CPS-1 contouring program. Contour intervals used for plotting conductivity and magnetometry data were 10 mmho/m and 50,000 gamma/m, respectively. These intervals were chosen to show trends in areas of subtle changes, while maintaining distinction in areas of contrasting data.

The CPS-1 program contours data by dividing each grid cell into intermediate sub-cells. An intermediate grid value is then computed as the average of the four corner values and located at the center of the sub-cell with diagonals to each corner. The intersections of the contour locus with the sides and temporarily computed diagonals are determined using inverse linear interpolation. The process continues until each chosen contour interval is completed.

4.2 RESISTIVITY

VES data were analyzed using one-dimensional modeling. One-dimensional modelling assumes that the earth in the vicinity of the VES survey can be represented by a series of flat-lying layers, each with a different electrical resistivity. This interpretation gives accurate results if certain criteria are met:

- the geologic structure to be located has a significantly different resistivity than its background;
- the lateral extent of these structures must be larger than their depth; and

- the layers must be relatively thick compared with their depth.

The interpretations were done using an automatic inverse modeling computer program initially developed by Dr. Adel A.R. Zodhy of the Water Resource Division, U.S. Geological Survey, in July 1980 and updated in August 1986. The computer program begins with a best-fit estimation based on Ghosh coefficients and tentatively converges to the geoelectric model which gives the least sum of squared residuals for the field data. The program then generates layer thicknesses, depths and resistivities.

For geologic environments such as that at the 881 Hillside area, where more than four layers are present and the layers are not flat-lying, lateral interferences affect calculations for both the layer thicknesses and layer resistivities. Wherever the lateral difference error exceeds 33%, the data were smoothed to reduce the error as much as possible and then were analyzed. The smoothing technique used consists of digitizing the data curves by reducing the high and low resistivity spikes in the field data prior to analysis for layer thickness and layer resistivities.

4.3 MAGNETOMETRY

Interpretation of the magnetic data consisted of three phases. The first phase removed diurnal variations in the earth's magnetic field from the field data using a linear interpolation method. The field data were also checked for regional gradient effects. Due to the small size of the 881 Hillside area, this was not a problem. The second phase generated the gradient data from the field data by dividing the difference between top and bottom sensors by the distance between sensors. The third phase developed computer generated contour plots of equal magnetic intensity called isogams.

The contour plots, as discussed in Section 4.1, were then compared to the electromagnetic survey for interpretation. No analytical modeling of the data was done to determine either shape or depth variables nor any geologic modeling to develop a stratigraphic model. All interpretation was based on a visual comparison of the contour plots with published magnetic curves of simple geologic models to determine whether the anomaly was attributable to geologic conditions or cultural interferences.

4.4 METAL DETECTOR

No data interpretation was required for the metal detector survey. Areas of buried metallic items were located in the field and marked with pin flags.

SECTION 5

SURVEY RESULTS

5.1 ELECTROMAGNETIC CONDUCTIVITY

EM data values show a general increase in conductivity from the top of the 881 Hillside area to the lower areas of the slope from 40 to 70 mmhus/m This probably results from changes in soil moisture content with distance down the slope. Examination of contour plots (Appendix A) of the electromagnetic data shows several areas of anomalous conductivity which are not readily explainable by the occurrence of cultural interferences. The approximate locations, based on the Rocky Flats grid system, of the anomalous conductivity values for each instrument are as follows and presented on Figure 2.

EM-34 Vertical		EM-34 Horizontal		EM-31	
N-34760	E-20740	N-34760	E-20740	N-34750	E-20680
--------	--------	--------	--------	N-34750	E-20830
N-34820	E-21100	N-34820	E-21100	N-34810	E-21130
--------	--------	N-34940	E-21280	--------	--------
--------	--------	--------	--------	N-34975	E-21640
N-35120	E-21280	--------	--------	--------	--------
--------	--------	--------	--------	N-35665	N-22060

The above data show a good correlation between anomalies detected with the EM-34-3 in horizontal and vertical dipole orientations. There is less correlation between EM-34-3 and EM-31 anomalies. This difference is the result of varying depths of penetration and intercoil spacing of the instruments. The EM-31 is more sensitive to small conductors than is the EM-34-3, but also has a more shallow depth of penetration. The instruments are therefore measuring conductivity changes over different intervals and are not expected to produce duplicate data.

The conductivity anomaly located near grid point N-35120, E-21280 is located in a low-lying area off the end of SWMU-107, extending laterally across SWMU-106. The shape of this anomaly suggests the presence of a trench at this location. An area of anomalously low conductivity values identified near grid point N-34760, E-20740 appears in the field to be debris (possibly asphalt) which has been deposited on the slope. This may represent the location of fire debris which was apparently dumped on the site and has been identified as SWMU-130. Potential explanations of other anomalies are unknown. Subsurface sampling planned for the 881 Hillside area may provide additional explanations.

5.2 RESISTIVITY

The results of the VES surveys are presented as resistivity models in Appendix C. The VES surveys were then analyzed for stratigraphic interpretations as geoelectric models. A geoelectric model calculates a resistivity value for each a-spacing (electrode spacing). Stratification of the geoelectric model was based on changes of resistivity at each a-spacing. The changes were grouped together and the simple average of the resistivities was assigned to the group. Actual stratigraphic changes may not correspond to the geoelectric changes due to the averaging effect of the model.

At VES-1 (Figure C-1), two highly resistive zones appear at the surface, corresponding to compacted fill with construction debris and compacted soil due to the area's usage as a storage facility for various on-site contractors. Below 2.2 meters (7 feet), the resistivity is 415 ohm-meters, normal for dry, silty and sandy gravel. The value of 640 ohm-meters may represent dry sandstone bedrock. Below this layer at a depth of 8.8 meters (28.7 feet), a value of 110 ohm-meters may result from the presence of wet claystone bedrock. The lower than normal resistivity values may indicate that claystone bedrock contains a high percentage of clay with a high cation exchange capacity.

The survey at VES-2 (Figure C-2) indicated a layer approximately 2 feet thick with a resistivity of 260 ohm-meters representing colluvium. This layer overlies a stratum with a resistivity of 210 ohm-meters and a thickness of 7.4 feet likely composed of a slightly moist gravel. This stratum is underlain by a layer with a resistivity of 275 ohm-meters most likely representing a weathered bedrock composed of interbedded sandstone and claystone. Two additional layers were found below the weathered bedrock stratum with resistivities of 350 and 180 ohm-meters. These resistivities may result from a change in bedrock from a predominantly dry sandstone bedrock to a claystone and sandstone bedrock sequence.

VES-3 (Figure C-3) exhibited a similar response to VES-2 with the exception of the surface layer. The resistivity of the surface layers, 895 and 580 ohm-meters, was higher than the surface layer at VES-2. These layers probably represent very dry colluvium with an increase in moisture content at depth. Below these strata, the geoelectric model for VES-3 was approximately the same as that of VES-2.

Both VES-4 and VES-6 (Figures C-4 and C-6) had similar responses to one another. VES-4 had a greater thickness of resistive layers probably representing colluvium and gravel strata than did VES-6 (9 and 2 meters, respectively). The bedrock resistivities for both surveys ranged from 105 ohm-meters to 390 ohm-meters. This was interpreted as claystone bedrock overlying sandstone bedrock. During analysis of the geoelectric models for these survey points, a thin, highly conductive layer was encountered at the top of the bedrock surface. This layer was tentatively identified as a possible perched water condition overlying the bedrock. The analytical model ignored this due to the model's theoretical basis which assumes the unit to be relatively thick compared to its depth.

VES-5 and VES-8 (Figures C-5 and C-8) displayed responses similar to VES-4 and VES-6. In general, VES-5 and VES-8 had lower resistivities (90 to 420 ohm-meters) than VES-4 and VES-6. The explanation for this difference appears to be wetter conditions at VES-5 and VES-8 as observed in the field. A layer present beneath (>1 m deep) the surface colluvium layer at VES-8 had a lower than expected resistivity of 160 ohm-meters which was assumed to be the gravel stratum typically found below the colluvium. This lower resistance appears to be the result of saturated conditions within the gravel layer.

At VES-7 (Figure C-7), a change in resistivity at a depth of less than one meter within the assumed vadose zone appears to be a colluvium strata overlying a gravel stratum. Within the gravel stratum, a layer of reduced resistivity probably indicates the saturated zone. The resistivity values below the assumed saturated gravel stratum are similar to those encountered elsewhere. The values are typical of a claystone and sandstone interbedded sequence having resistivity values on the order of 170 to 200 ohm-meters and a claystone sequence having resistivities on the order of 90 to 130 ohm-meters.

VES-9 (Figure C-9) was located based on the reported location of SWMU 104. As shown on Figure C-9, significant resistivity changes occur in the upper 15 feet of the geoelectric model. A distinctive lower resistivity (270 ohm-meters) occurs between two resistivity values generally associated with the gravel stratum. This may result from the presence of a stratum of conductive material (e.g., contaminants) different from the gravel stratum. Below this sequence of resistivity changes, resistivity values typical of claystone and sandstone bedrock were found.

5.3 MAGNETOMETRY

Two general anomalous areas were detected during the magnetic survey, as shown on the contour plot presented in Appendix B. The first anomalous area was the southwestern section of the 881 Hillside area, south of Building 881. Numerous anomalous highs and lows, ranging from 45,000 to -30,000 gammas/m, were noted in this area. The majority of these anomalies are due to cultural interferences including disturbed ground, Western Slope Gas Company's natural gas pipelines (both the abandoned and active lines), culverts and other structures placed by Rocky Flats personnel to reduce soil erosion, and underground utility lines.

There are anomalies which are not related to cultural features. Four of the magnetic anomalies identified on the southwestern section of the 881 Hillside area corresponded to conductivity anomalies defined during the electromagnetic conductivity survey. The magnetic anomalies corresponding to the conductivity anomalies are located at the following grid points:

Magnetic Anomalies Corresponding to Conductivity Anomalies	
N-34750	E-20830
N-34760	E-20740
N-34750	E-20680
N-34820	E-21100

It is thought that the anomalies located at the above locations are the result of large concentrations of metallic objects which have been deposited on the site.

The second general anomalous area was along the top of the north ridge of the 881 Hillside area, east of Building 881. Numerous anomalous highs and lows, ranging from 45,000 to 30,000 gammas/m, were noted in this area. Examination of the top of the 881 Hillside shows extensive amounts of metal debris which has been deposited over the years. Due to magnetic noise in this area, no meaningful data interpretation was possible.

5.4 METAL DETECTOR

The metal detector surveys in the southwestern section of the 881 Hillside area consisted of investigating the reported locations of SWMUs 102, 103, 104, 106, 107, 130, and 177, various cultural interferences, and conductivity and magnetic anomalies. No buried metallic items were encountered at SWMUs 102, 103, 104, 106, and 107. The overhead lines and chain link fence at SWMU-105 created sufficient magnetic noise that no readings were possible. Cultural interferences included Western Slope Gas Company's natural gas pipeline which was located in the field and pin flagged for reference and a second Western Slope Gas Company natural gas pipeline which was located south of the present line, but terminated at the interceptor ditch further south of Building 881.

Additional cultural interferences located during the survey included the outfall pipe (SWMU 107) from Building 881 to the holding pond and from the holding pond to the interceptor ditch. Another pipeline (SWMU 106) was located west of this pipe, but could not be traced further than 10 feet north of where it is exposed in the interceptor ditch. All structures were located in the field and marked with pin flags for future reference.

The reported location of SWMU 104 and the northern ridge east of Building 881 were investigated. No metallic items were detected at the reported location of SWMU 104. Metal detector response indicated that the top of the northern ridge holds large quantities of buried metallic items. A number of these items were exposed at the surface and consisted of reinforcing bars encased in concrete. The area contained such a large quantity of metallic items that the areal extent was defined in gross terms as the top of the northern ridge. South of the northern ridge, Western Slope Gas Company's existing natural gas pipeline was present. The pipeline was located in the field and marked with pin flags.

SECTION 6

CONCLUSIONS

Geophysical surveys of the 881 Hillside area of the Rocky Flats Plant were carried out in order to investigate and identify, as possible, the location of SWMUs, and to provide information about subsurface conditions upon which to plan subsequent portions of the RI/FS investigation. The data obtained resulted in the identification of areas of anomalous geophysical response to be investigated as specified in the CEARP IGMP/SSMP Sampling Plans. The geophysical surveys, in conjunction with soil gas results, were used to plan areas for subsurface investigation, monitoring well installation, and groundwater sampling.

The locations of the apparent geophysical anomalies are identified on Figure 2. Anomalies were identified by electromagnetic and magnetic methods near the south ends of SWMUs 106 and 107, and off the southwest corner of SWMU 130. The cause of the anomalous readings obtained from these locations is unknown. However, the shape of the anomalies near SWMUs 106 and 107 suggest that a trench may be located at this position. The anomaly located off the southwest corner of SWMU 130 cannot be identified at this time. Individual electromagnetic anomalies, possibly resulting from buried fire debris, were also observed near the western and southern margins of SWMU 130. The locations of each of these anomalies has been compared to known cultural interferences. No apparent cultural interference could be identified as being responsible for these anomalies. Large areas of the northern and southwestern portions of the 881 Hillside area contained sufficient magnetic debris to make meaningful data interpretation impossible. The magnetic anomalies identified on Figure 2 therefore represent areas of anomalous readings which correlate with electromagnetic anomalies. Vertical Electrical Soundings were completed at nine survey points in order to provide information on site stratigraphy. The results of each of the above geophysical surveys are discussed in detail in Section 5.

Quality Control data for each instrument were collected as specified in the CEARP Quality Assurance Plan. The resulting data indicates that instrument functions and operating procedures were properly conducted. Details of quality control procedures are provided in Section 7.

SECTION 7

QUALITY CONTROL

7.1 ELECTROMAGNETICS

The EM-31 and EM-34-3 instruments were operated in accordance with the operating instructions provided by the manufacturer, Geonics, Ltd. In order to detect and correct for any drift of the instruments during the course of the surveys, base stations were designated at the beginning of each survey. Prior to beginning each day's survey, measurements were taken at the base station and compared with previous readings. Base station readings were repeated at frequent intervals throughout the survey day. Other instrument functions checked during base station visits included meter null, sensitivity checks, and battery charge. Quality control data from each instrument is provided in Table I.

7.2 RESISTIVITY

The VES system was operated in accordance with the operating instructions provided by the manufacturer, Bison Instruments, Inc. The system was checked for drift at the base station established for the electromagnetic conductivity instruments (N-36200, E-22300). The system was set up and two sets of readings were obtained. The two sets of readings were always within +/- 5% of one another.

Upon completion of each VES survey, the data were cross-checked according to procedures provided by the manufacturer. Millivolt readings were obtained from the five array patterns (see Figure 3) for each a-spacing. The cross checks were as follows:

- o A>C>D1;
- o D1~D2; and
- o A-C~B

TABLE I

QUALITY CONTROL DATA

Instrument: EM-34-3

Base Station: N36200, E22300

Date	Time	Vertical Dipole	Horizontal Dipole	Battery	Null
3/25/87	1310	40	38	OK	OK
3/25/87	1625	37	38	OK	OFF 1 mmho/m
3/26/87	0900	38	38	OK	OK
3/26/87	1230	40	38	OK	OFF 1 mmho/m
3/26/87	1547	40	38	OK	OK
3/30/87	1015	40	38	OK	OK
3/30/87	1320	38	38	OK	OK
3/31/87	0850	39	38	OK	OK
3/31/87	1150	39	37	OK	OK
3/31/87	1603	37	37	OK	OK
4/1/87	0850	37	37	OK	OK
4/1/87	1225	36	39	OK	OK
4/1/87	1520	12	12	OK	OFF 1 mmho/m
4/1/87	1525	38	36	OK	READJUSTED
4/2/87	1250	40	38	OK	OK
4/2/87	1500	37	34	OK	OK

Instrument: EM-31

Base Station: N36200, E22300

Date	Time	Reading	Battery	Null
4/8/87	1220	32	OK	OK
4/8/87	1530	32	OK	OK
4/10/87	0900	34	OK	OK
4/13/87	0920	34	OK	OK
4/13/87	1245	32	OK	OK
4/13/87	1520	32	OK	OK
4/14/87	0810	32	OK	OK
4/14/87	1255	32	OK	OK
4/14/87	1620	31	OK	OK
4/15/87	0810	31	OK	OK
4/15/87	1245	31	OK	OK
4/15/87	1620	30	OK	OK
4/16/87	0830	31	OK	OK
4/16/87	1230	32	OK	OK

No repeat readings were required for any of the nine VES survey points. A battery check was also conducted each morning and at the end of the survey day. When the battery indicators approached 11.4 volts, the batteries were recharged overnight.

7.3 MAGNETOMETRY

The magnetometer was operated in accordance with the operating instructions provided by the manufacturer, EG&G Geometrics. Prior to beginning the magnetic survey, a swing test was conducted at the base station to detect any directional sensitivity of the sensor. Each swing test consists of three sets of four readings, each taken with the sensor oriented at 90^{o} from the other. If direction sensitivities were detected, they were corrected by scrubbing the sensors with detergent and water. The sensors were then retested. The results of the swing tests are presented below:

SWING TEST RESULTS

Swing Test No.	Date	Swing	North (gammas)	East (gammas)	South (gammas)	West (gammas)
I	3-30-87	1	54,560.7	54,562.3	54,561.7	54,561.0
		2	54,564.3	54,560.7	54,562.7	54,561.3
		3	54,563.9	54,560.4	54,560.4	54,560.3
II	3-30-87	1	54,558.1	54,557.9	54,557.9	54,558.1
		2	54,558.2	54,558.2	54,558.1	54,558.1
		3	54,558.3	54,558.3	54,558.4	54,558.4
III	4-8-87	1	54,860.4	54,860.6	54,860.4	54,860.5
		2	54,861.0	54,860.9	54,860.8	54,860.5
		3	54,860.3	54,860.5	54,860.5	54,860.3

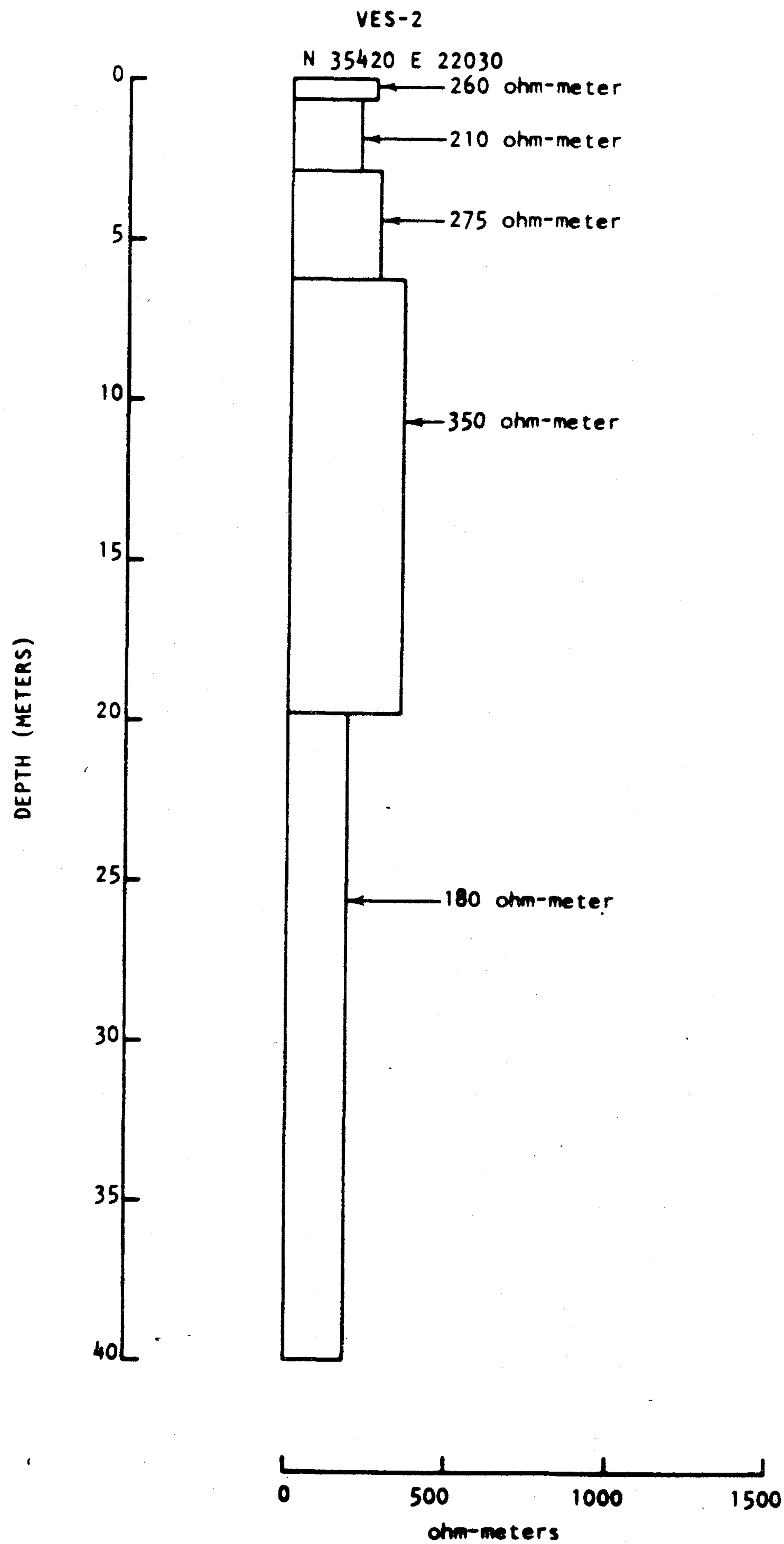
Notes: 1) Swing test #I failed
2) Swing test #II accepted
3) Swing test #III accepted

The magnetometer was held in a north-south direction with the operator standing to the west of the sensors in an attempt to standardize any effects the operator and mode of operation would have on the instruments. Batteries used in the instrument were industrial heavy-duty D-cell batteries with cardboard jackets to further reduce any

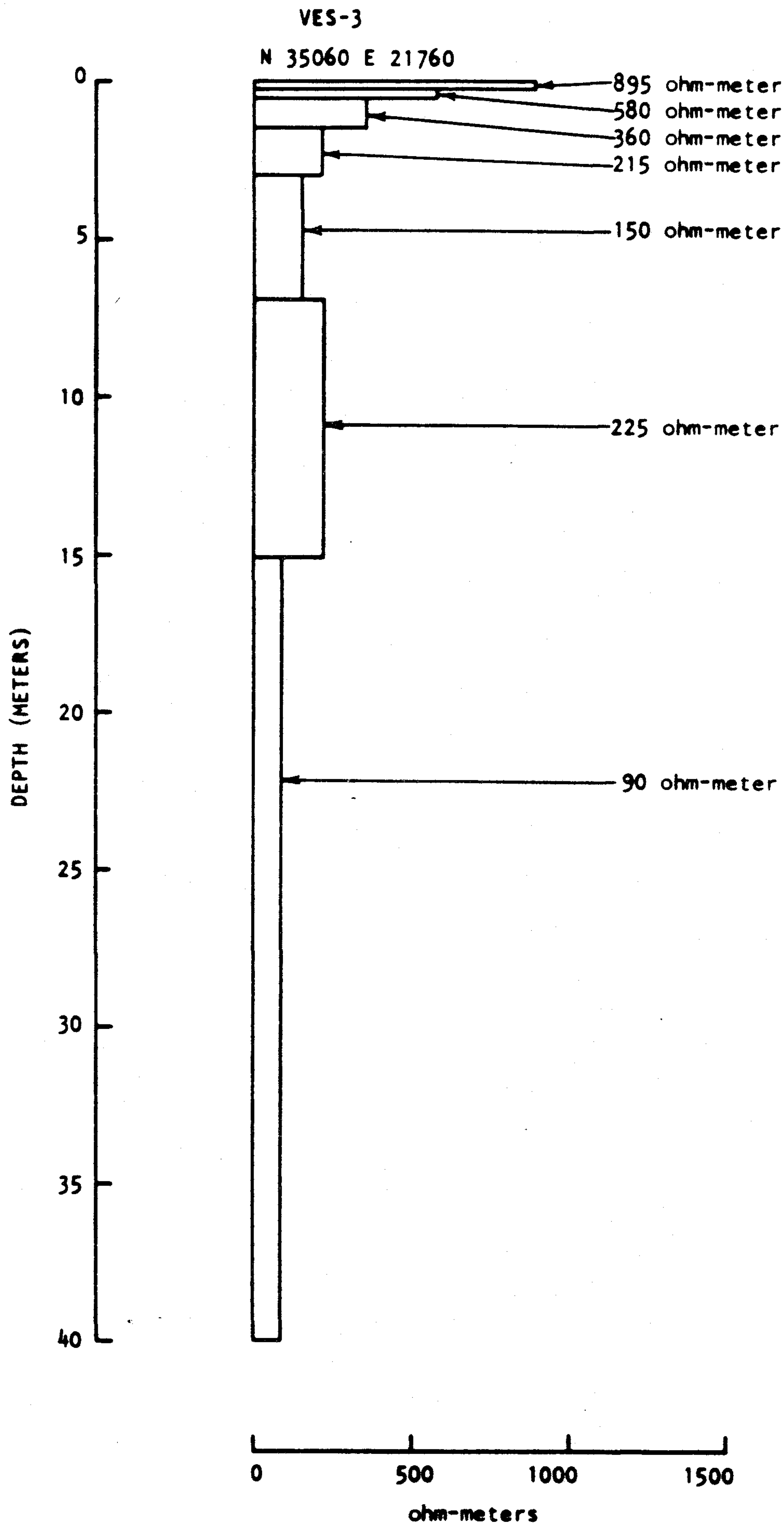
APPENDIX A

APPENDIX B

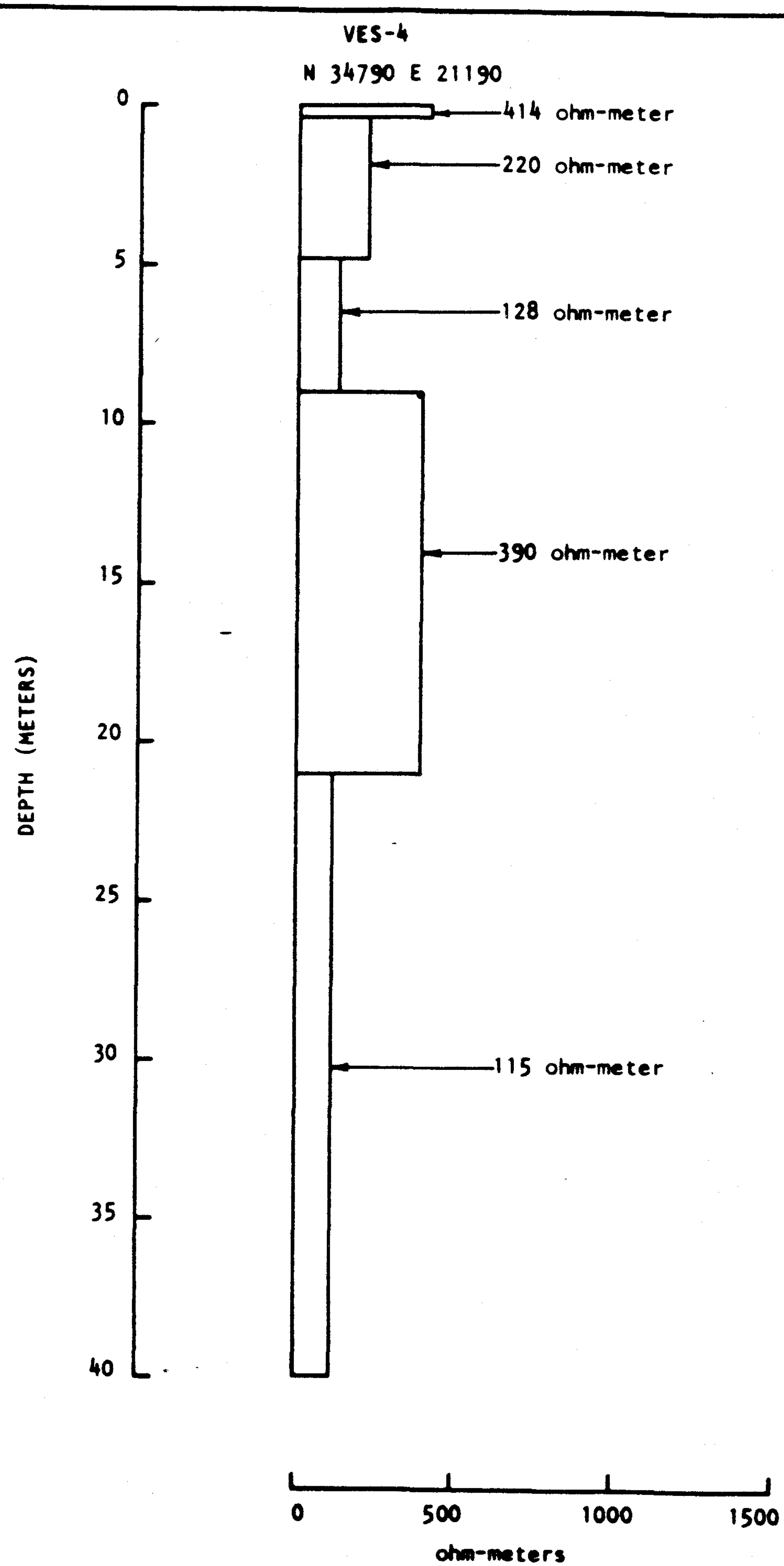
APPENDIX C



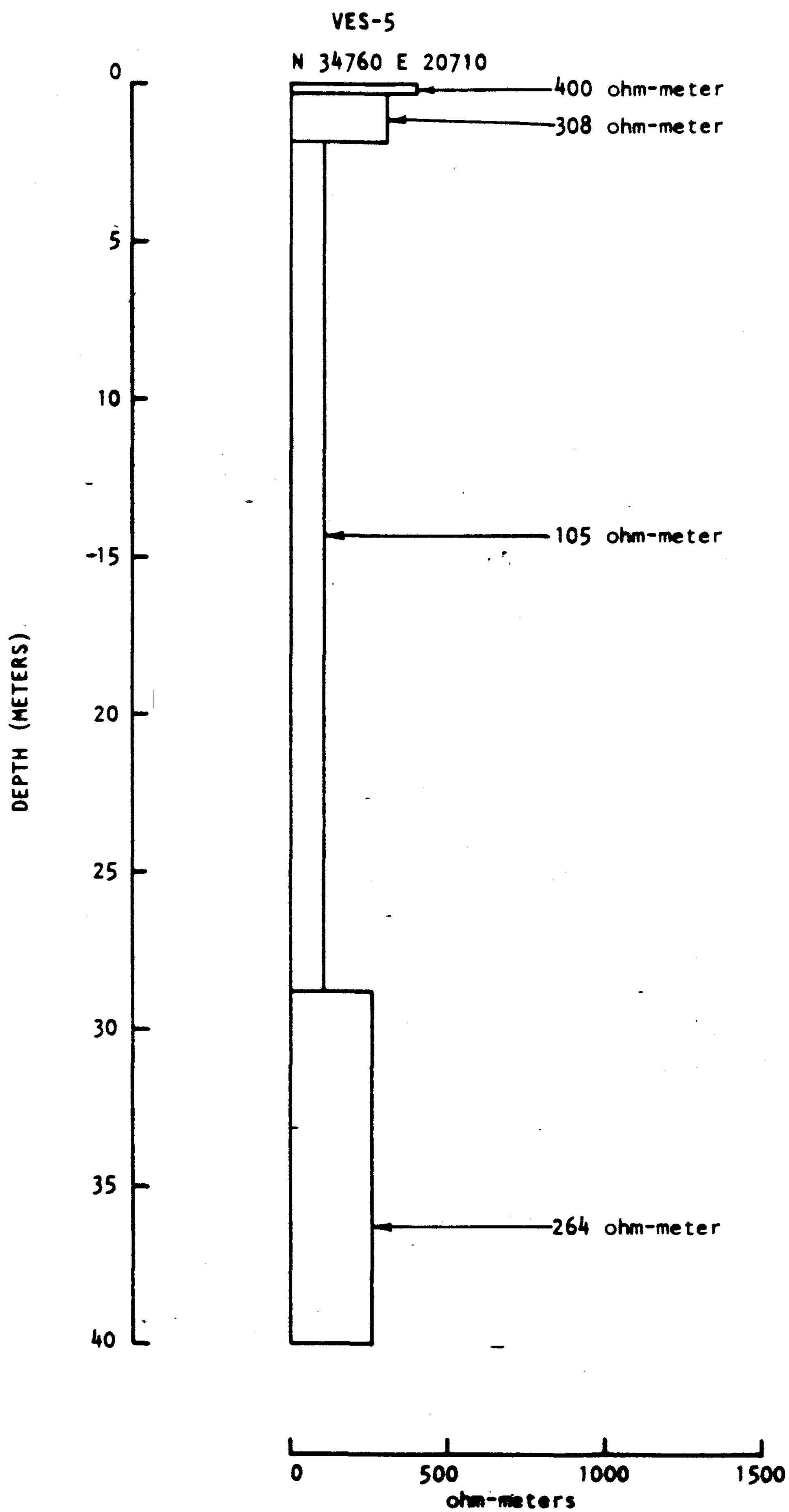
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-2	Fig. C-2



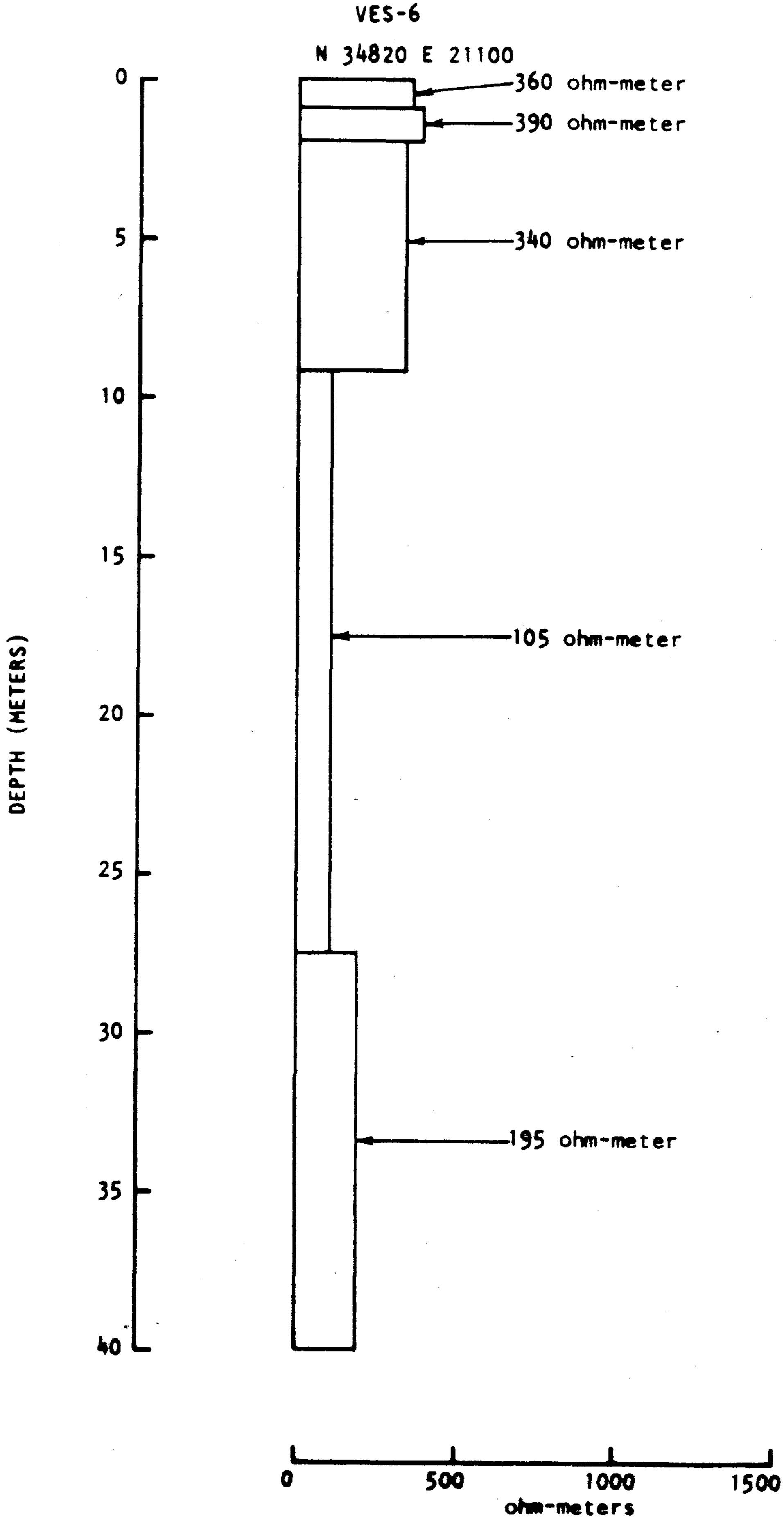
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-3	Fig. C-3



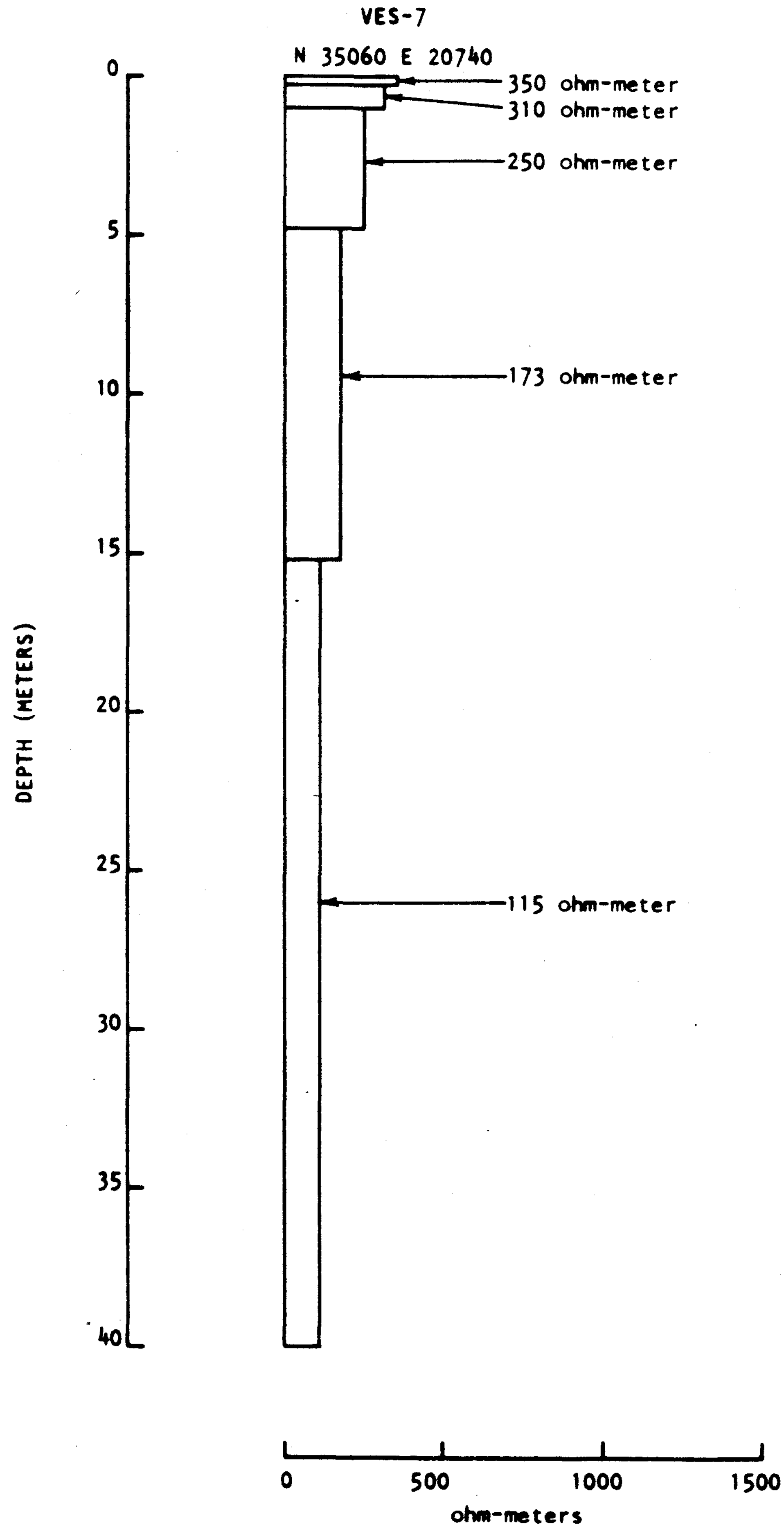
6 007 87	**Chen & Associates**	INVERSION RESULTS FOR VES-4	Fig. C-4



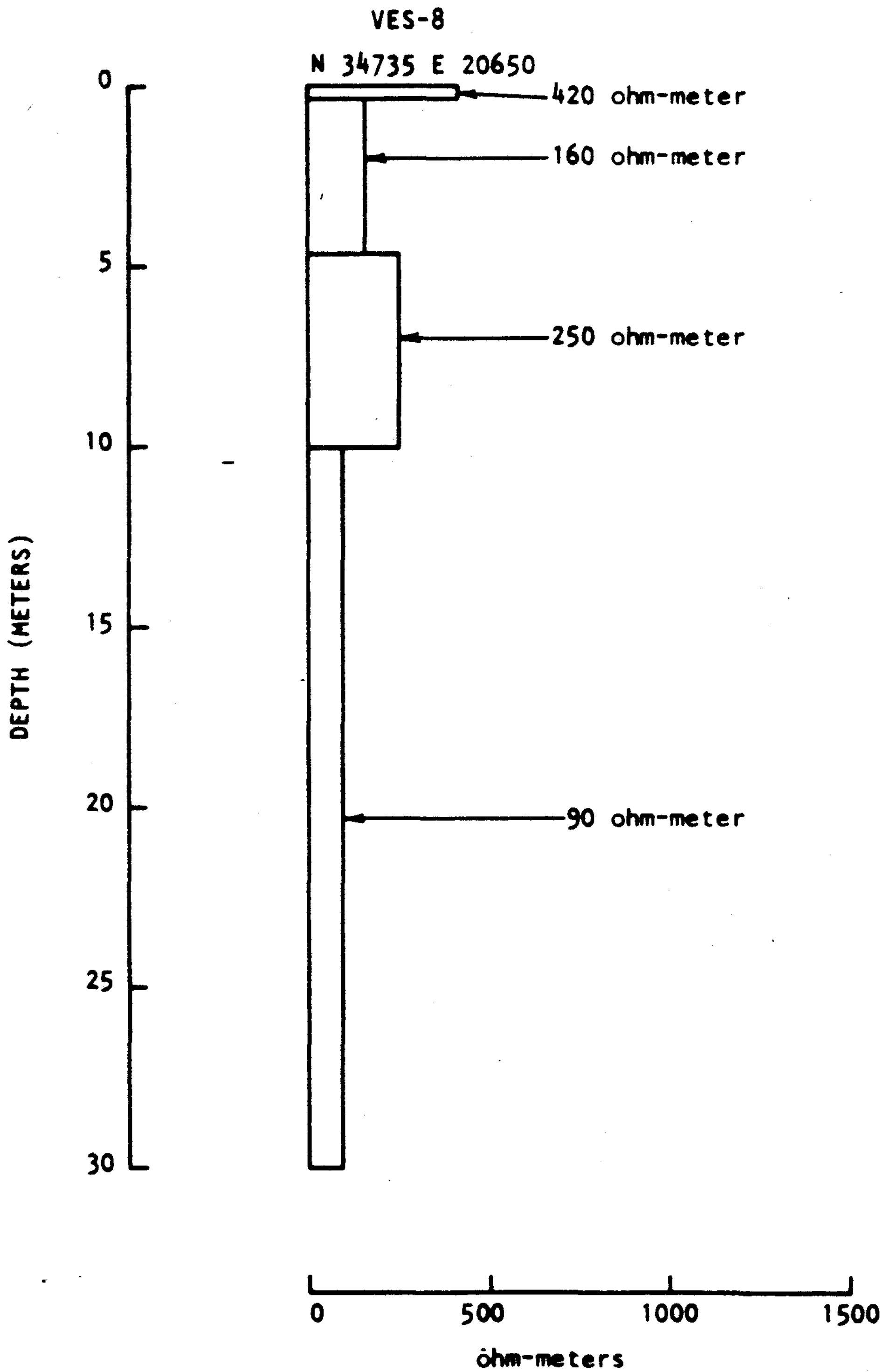
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-5	Fig. C-5



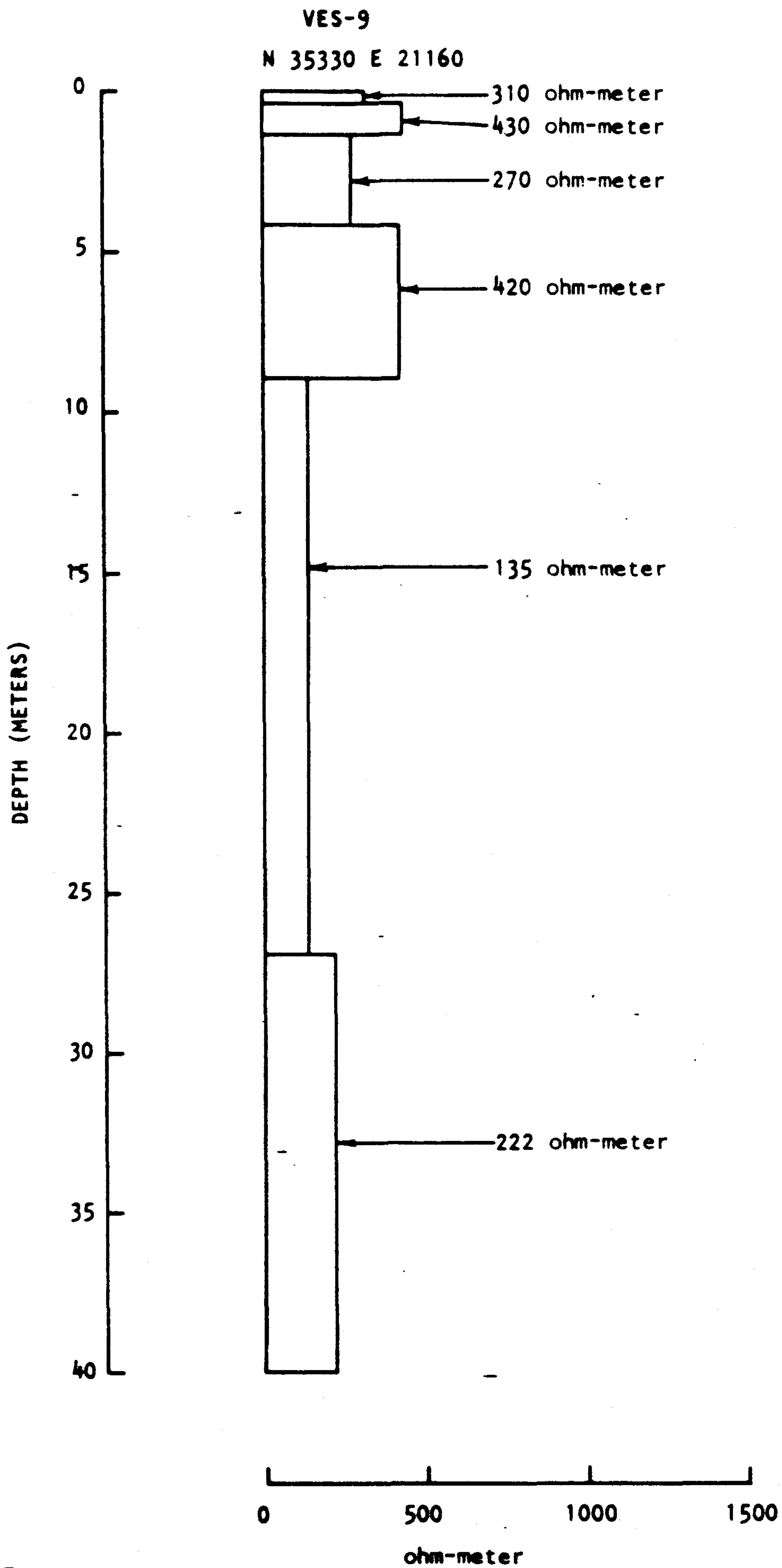
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-6	Fig. C-6



6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-7	Fig. C-7



6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-8	Fig. C-8



6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-9	Fig. C-9

APPENDIX B

SOIL GAS SURVEY

1.0 INTRODUCTION

A soil gas technique was used as a reconnaissance tool to locate and identify areas of subsurface organic contamination. This method provides an efficient, economical means by which trace quantities of subsurface derived organic contaminants can be detected on the ground surface. For the 881 Hillside remedial investigation, the objective of the work was to determine the presence and relative concentrations of 1,1-dichloroethene; 1,1,1-trichloroethane; carbon tetrachloride; trichloroethene and tetrachloroethene in shallow soils. These volatile compounds are known to be present in the ground water, and the distribution of these compounds in shallow soils can be an indication of their distribution in ground water. Thus, the soil gas survey is used to provide a preliminary delineation of plume boundaries so that monitoring wells can be effectively placed to confirm contaminant plume locations.

The remedial investigation plans called for real time measurement of soil gas. Real time measurements are extracted by inserting a hollow conduit into the soil to a given depth and evacuating a predesignated volume of gas. After the system has been purged of any atmospheric air, a sample is extracted and analyzed, either on-site or in a remote laboratory. The advantages of this procedure are that the data are, in general, available more quickly than time integrated methods. The disadvantages are the added equipment required to do the sampling and analysis and a reduction in the mobility of the sampling vehicle. In addition, real time methods increase the lower detection limit.

Considerations of decreased mobility, lower detection limits, and heavy traffic on grasslands influenced Rockwell's decision to re-evaluate this method, and to substitute Petrex's time integrated method.

Petrex's time integrated method employs activated carbon to collect the contaminants for a period of time specifically determined for the site to concentrate the contaminant to a level that might otherwise be undetectable. Time integration also alleviates any variations in the contaminant concentrations due to transient situations that might not reflect the true conditions (e.g., fluctuations in barometric pressure, rain percolating through the soil, and porosity differences in the soil). In addition, all equipment required to perform the sampling can be carried into the target area by two individuals, thus reducing traffic in areas where heavy traffic might cause re-suspension of soil possibly contaminated with radioactive contaminants. Rather than mass per unit volume measurements that are the result of real time gas chromatographic analysis, the time integrated results are measured in terms of ion counts determined by mass spectrometry of heat-purged compounds from the activated carbon. A synopsis of the Petrex method is shown in Attachment 1.

2.0 PROCEDURE

2.1 METHODS

The sample collector consists of a ferromagnetic wire coated with an activated carbon which is inserted into a resealable glass tube. A two-inch rod is driven approximately eighteen inches into the soil and the sample collector is inserted into the resulting hole. Soil is then packed into the hole, covering the tube. Attachment 2 contains the field instructions that were followed.

The optimal exposure period for volatile organic detection was established by positioning time calibration collectors that were removed at 7, 9, and 11 days, and subsequently analyzed. The analysis of these collectors indicated that soil gas flux was slow, and therefore a twenty-one day incubation period was established to maximize adsorption of soil gas compounds but allow completion of the work in the short time frame.

After twenty-one days, the tubes were removed and the carbon analyzed for contaminants by Curie-Point mass spectrometry. The carbon is burned at the Curie-Point temperature of the ferromagnetic wire releasing and ionizing the adsorbed compounds. The ions are subsequently separated and identified in the mass spectrometer. Spectrographs representing total ion counts versus mass/charge were generated for each collector. These "fingerprints" allow computerized identification of individual species.

2.2 QUALITY ASSURANCE/QUALITY CONTROL

In order to assure the contaminant-free sampler for emplacement and instrumental analysis, quality control procedures were strictly followed. Quality

Assurance and Quality Control procedures can be found in Attachment 3. For example, to assure contaminant-free samplers, the samplers are assembled in an inert atmosphere. Samplers are periodically removed from each batch and analyzed to detect any contamination. During mass spectral analysis, calibration and periodic background checks are routine. Field duplicates and blanks were also deployed to ensure consistent results. These results can be found in Appendix F, Table F-2.

2.3 SURVEY GRID

Rocky Flats Plant coordinates were surveyed and staked to establish a sixty-foot by sixty-foot grid for which samplers were to be placed at nodes every 120 feet. This remedial investigation plan grid spacing for the soil gas stations was determined to be inconsistent with Petrex's recommended alignment. Therefore, samplers were placed every 120 feet along a grid line using sixty-foot offsets for each successive grid line. This offset grid was designed so that adjacent grid lines are sampled at non-aligned stations, thus interrupting the orthoganol pattern of a uniform grid. One hundred and eight samplers were installed.

2.4 PLUME MAP

The relative ion count intensity of individual vapors collected are correlated with the sample locations of the survey grid. These relative intensities have been plotted to infer concentration gradients and source locations. Data are presented on Plates 3-2 through 3-5.

APPENDIX B

ATTACHMENT 1

PETREX ENVRIRONMENTAL ANALYSES

ATTACHMENT 1
Petrex Environmental Analyses

Description of Petrex Soil Gas Technique for collection and identification of trace volatile organic compounds.

1. Collection - Activated carbon which is bonded to a ferromagnetic wire is placed in a glass tube and buried just below the soil surface. After a pre-determined collection period (3-30 days), the tubes containing carbon-bearing wires are retrieved, sealed and taken to the laboratory for mass spectrometric analysis.

2. Analysis - The organic gases adsorbed on the carbon are purged from the carbon, separated according to ion mass, counted and a mass spectrum of masses from 29 to 240 is drawn.

3. Identification - These mass spectra are compared with mass spectra derived from known volatile organic compounds and the compounds are identified.

4. Derivation of relative total counts for mapping purposes - The relative ion count intensity (relative intensities) of the gases collected on various collectors are correlated with sample locations on a map of the survey area. These relative intensities are useful for inferring relative differences in the concentrations of the compounds in the soil or ground water, which can be used to help determine the direction of source areas and/or direction of movement of contamination.

NOTES:

These surface collections and analyses cannot be used to determine the depth to the source contaminants.

Because compounds can be differentiated by their spectra, analyses from the carbon collectors can be used to help differentiate multiple source areas.

Most areas have a natural background of trace emanations from naturally occuring compounds. The distinction of this background from contamination is facilitated by Petrex's three and one-half years in resource exploration and environmental surveys, which have resulted in the examination of more than 50,000 of these spectra.

APPENDIX B

ATTACHMENT 2

FIELD INSTRUCTIONS

FIELD INSTRUCTIONS

1) Dig sample location 10-12 inches deep and approximately 2-4 inches in diameter. Do not contaminate the soil. (UNDER ASPHALT OR CEMENT - 2'-3' BELOW BASE OF ASPHALT OR CEMENT)

2) Remove the cap and immediately place sampler (vertically with open end down) into sample location hole. The sampler tube must be at least two inches below ground surface. Immediately cover the sampler with soil.

3) Return the cap to one of the clean plastic bags provided.

4) Mark the sample location with flagging or other material. Note the sample location on a base map and enter information in a field notebook.

5) Retrieving samples - (should be done at the recommended time intervals).

   (A) Remove the soil until tube is exposed.

   (B) Take a cap from sealed plastic bag. Check for blue teflon liner inside cap. If liner has fallen out, replace it.

   (C) Remove tube from the hole. If wire falls out of tube or if tube is broken, use tweezers to handle wire.

   (D) Wipe off the tube and threads thoroughly with a clean, dry cloth. If the tube threads and lip are not properly cleaned, the cap will not seal and the sample will become contaminated.

   (E) Seal tube with cap making sure the teflon liner is seated to tube lip.

   (F) Place sticker on <u>cap</u> top and number. Number sequentially starting with 1. Use <u>only</u> numbers to identify samples. For two wire samplers, use two consecutive numbers. Please underline all numbers for easy identification. Do not duplicate cap numbers.

   (G) Record number or numbers of sampler corresponding to location on base map and field notebook.

   (H) Do not place tape, sticker, or glue on glass tube. Stickers provided will adhere if placed on dry cap.

6) When packaging exposed tubes, <u>please do not use Styrofoam or popcorn packing</u> as this can potentially introduce a contaminant. Enclose tubes in two plastic bags as provided and wrap each package tightly with bubble wrap.

The contents of this package should be as follows:

_____ Single Wire Tubes

_____ Double Wire Tubes

- To be placed in the survey area as if they were single wire tubes. These samples are to be used internally as QC and calibration samples.

_____ Field Blanks

- To be placed in the survey area with the caps still on, one blank placed each day until all blanks are used or place left over blanks on last field day.

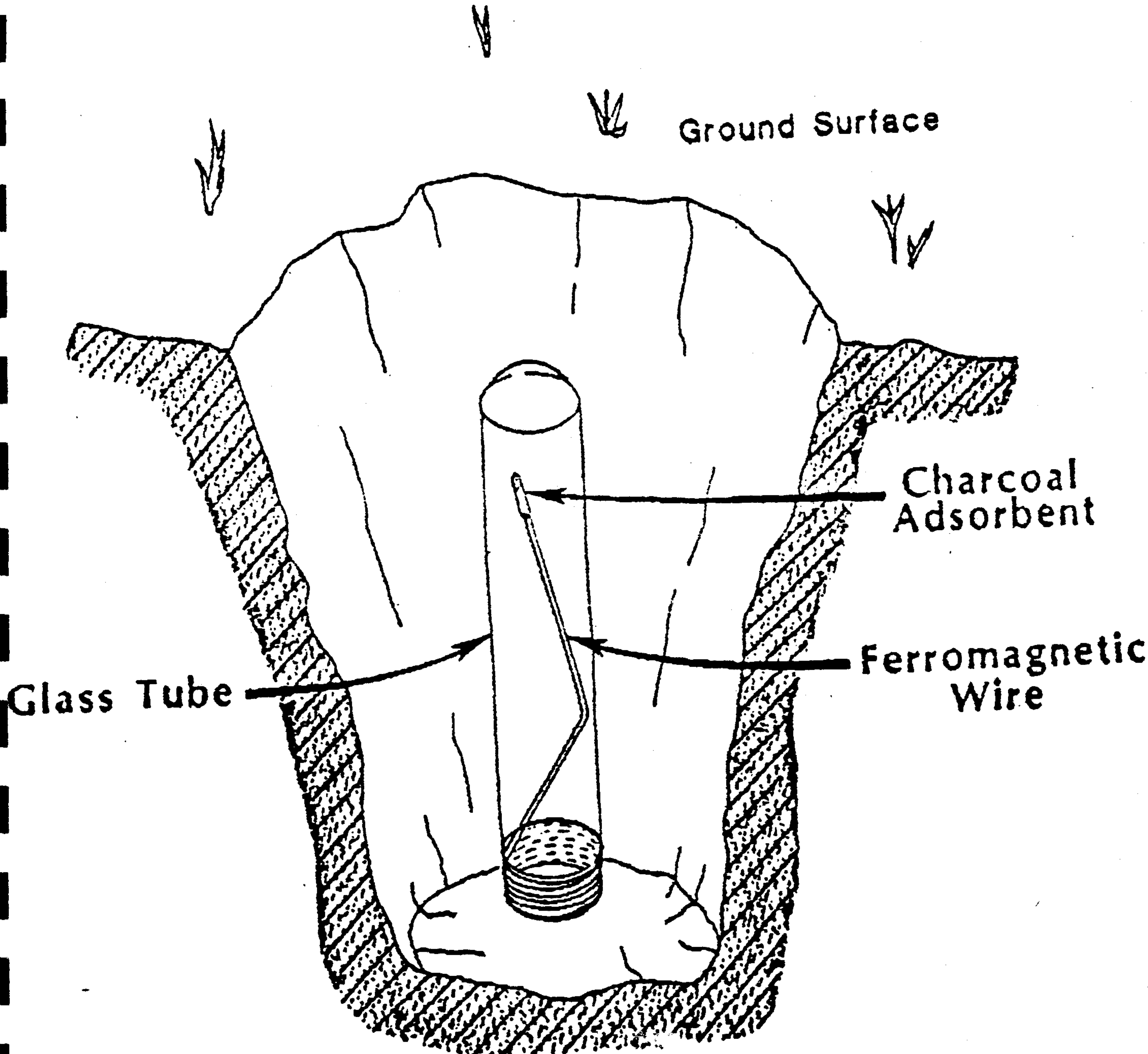
_____ Time Test

- To be placed over an area of suspected volatile compounds. When returning these samples to Petrex, please label them with Project # __________.

_____ Cap Labels

** CAUTION **

The most critical aspect of collector placement is not to expose the collector to contaminants. Smoking, exhaust fumes, etc., will contaminate the collector. Bands must be kept free of organics, including insect repellant, sunblock, gasoline, motor oil, cosmetics, etc. The lip and inside of the tubes, caps, and cap liners must not contact any contaminants.


Ground Surface
Charcoal Adsorbent
Ferromagnetic Wire
Glass Tube

APPENDIX B

ATTACHMENT 3

PETREX QUALITY CONTROL/QUALITY CONTROL PROCEDURES

PETREX QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

Wire Preparation

1. Sampler materials are processed through thermo-chemical cleaning procedures.

2. Adsorption wires (after construction) are cleaned by heating to 358 degrees C in a high vacuum system.

3. Wires are packed under an inert atmosphere in respective vials.

4. One collector out of every thirty is checked for contamination by mass spectrometry. Based on the results, the group of thirty collectors is approved for release into the field.

Sampler Shipment and Field Handling

1. Five percent transportation blanks are included with each shipment. Transportation blanks (2.5% of total) samplers are stored until analysis with the field samplers.

Mass Spectrometer Tuning

1. An Extranuclear Quadrupole Mass Spectrometer is used for collector analysis. Mass assignment and resolution are manually adjusted using a Perfluorotributylamine (PFTBA) standard. The mass offset value is entered into the computer followed by comparisons of a computer generated PFTBA spectrum. If correct mass (M/Z) values are obtained, the operator proceeds to the next tuning step. If not, Step 1 is repeated until correct masses are obtained.

2. Peak intensity ratios are set from the major peaks in the PFTBA spectrum using the following values:

Mass (M/Z)	Spectrum Intensities
69	= 100%
131	= 25% ± 5%
219	= 35% ± 5%
502	= 5% ± 2%

3. During tuning the ion signal for mass (M/Z) 69 of PFTBA is measured at a specific sample pressure and detector voltage and compared to previous operation values.

4. Electron energy (meter reading) is set to 15 electron volts and emission is set at 12 milliseconds. All other operating parameters, such as scans, scan range, mass offset are established in the computer program. These values (sensitivity) can only be changed by the laboratory manager.

5. Final detector voltage is established using the duplicate collector field sample.

MASS SPECTROMETER ANALYSIS

1. Periodic (approximately every 20 samples) machine background analyses are performed to assure minimal influence from internal communication. If there are peaks that are not related to atmospheric gases, the supervisor is notified and the mass spectrometer is shut down and cleaned as necessary.

2. A written sample number record is kept during the analysis to prevent accidental cross numbering.

3. The mass spectrometer control program contains appropriate "flag statements" that prompts the operator with a warning if an inputted sample number has already been analyzed. The operator then checks the current number, along with the disk storage location of the previously entered number to identify the true numbering situation.

APPENDIX C
DESCRIPTION OF DRILLING ACTIVITIES

1.0 INTRODUCTION

This appendix describes the remedial investigation drilling program implemented at the 881 Hillside Area during May and June, 1987. The program consisted of soil sample collection from 17 boreholes and installation of seven new monitor wells to determine the nature and extent of soil and ground-water contamination. Borehole and monitor well locations were tentatively identified in the CEARP Remedial Investigation Plan (DOE, 1987b), and drilling, soil sampling, packer testing and monitor well installation procedures are presented in the Comprehensive Source and Plume Characterization Plan (DOE, 1987a) for Rocky Flats Plant. Presented below is a rationale for the final well and borehole locations followed by a discussion of any deviations from the drilling, soil sampling, packer testing, or well installation procedures.

2.0 DRILLING LOCATIONS

1987 borehole and monitor well locations are shown on Plate V. Drilling locations were selected to generally follow the CEARP Plan; however, actual locations were selected based on geophysical and soil gas survey results. Final drilling locations were selected by the Site Manager and approved by the Rockwell International CEARP Manager.

2.1 BOREHOLE LOCATIONS

Soil samples were collected from boreholes at the 881 Hillside to investigate reported Solid Waste Management Unit (SWMU) locations and to investigate soil gas contaminant plumes. According to the Remedial Investigation Plan, each reported SWMU would contain at least two sampling locations. This concept was followed in implementing the plan; however, some borehole locations were moved slightly to investigate detected soil gas contaminants or geophysical anomalies where they did not correspond to reported SWMUs. Presented below is a discussion by borehole of each sampling location.

Boreholes BH1-87, BH2-87, and BH3-87 are located in the vicinity of the Building 885 drum storage area (SWMU 177), the out-of-service fuel tanks (SWMU 105), the old 881 outfall pipe (SWMU 106), and the hillside fuel oil leak (SWMU 107) as specified in the SSMP. BH1-87 is located at soil gas point 92, where high molecular counts of PCE (34,448) and TCE (38,553) were detected. TCA and DCE were also detected at this soil gas point. BH2-87 is located due south of SWMU 106 at soil gas point 110. This location was chosen not only to investigate soil conditions downstream of the old outfall but also to investigate the PCE molecular count of 305 at soil gas point 110. BH3-87 is located due south of SWMU 107 to investigate soil conditions downstream of the hillside oil leak; no volatile organics were detected by the soil gas survey at this location. BH3-87 was completed as alluvial well 2-87 after soil samples were collected.

Boreholes BH4-87, BH5-87, and BH6-87 are located in the vicinity of the oil sludge pit (SWMU 102) and the chemical burial area (SWMU 103). BH4-87 is located near soil gas point 88 where a high molecular count of PCE (68,576) was detected. This borehole was moved approximately 30 feet west of soil gas point 88 due to overhead power lines. BH5-87 is located at the reported site of SWMUs 102 and 103 at soil gas point 77. No volatile organics were detected by the soil gas survey at this location. BH6-87 was located south of BH5-87 at soil gas point 106. This site is not a reported SWMU location; however, a PCE count of 1541 was detected by the soil gas survey at this location.

Borehole BH7-87 was drilled at the reported location of the liquid dumping area (SWMU 104) at soil gas point 69, where a PCE molecular count of 205 was detected with the soil gas survey.

Boreholes BH10-87 and BH11-87 are located in the revised location of the 800 Area Radioactive Site #1 (SWMU 130). The location of SWMU 130 was revised based on field reconnaissance, and the two boreholes were drilled within the revised SWMU location. Borehole BH11-87 is located approximately 50 feet southwest of soil gas point 116, where a PCE molecular count of 1120 was detected. Borehole BH10-87 is located approximately 90 feet south of BH11-87; no volatile organics were detected with the soil gas survey at this location.

Boreholes BH12-87, BH14-87, BH9-87, BH8-87, BH13-87, BH15-87, BH16-87, and BH17-87 are located in the multiple solvent spill area (SWMU 119). Boreholes BH12-87 and BH14-87 are located in an area of known volatile organic groundwater contamination on the 881 Hillside. BH12-87 is located at soil gas point 39 where high molecular counts of PCE (169,155) and TCE (17,241) were detected, and BH14-87 is located approximately 30 feet south of soil gas point 37 where high PCE and TCE molecular counts of 10,010 and 132,549, respectively, were also detected. BH9-87 is located approximately 190 feet northwest of BH12-87 at soil gas point 43. This borehole was placed upgradient of the volatile organic plume detected at boreholes BH12-87 and BH14-87 to determine the northern extent of the plume. Similarly, BH8-87 is located approximately 360 feet east of BH9-87, at soil gas point 19, to determine the eastern extent of the volatile organic plume. The soil gas survey detected a PCE molecular count of 299 at this location. BH13-87 is located within the reported location of SWMU 119.1 at soil gas point 56, where a PCE molecular count of 275 was detected by the soil gas survey. Boreholes BH16-87 and BH17-87 are located within the reported location of SWMU 119.2 at soil gas points 11 and 12, respectively. No volatile organics were detected with the soil gas survey at soil gas point 12. At soil gas point 11, PCE, TCA, and DCE were detected at molecular counts of 462, 659, and 819, respectively. BH15-87 was placed in the north central portion of the 881 Hillside at soil gas point 26 to investigate potential soil contamination near the top edge of the hillside. A PCE molecular count of 364 was detected at this location.

2.2 MONITOR WELL LOCATIONS

Seven new monitor wells (four alluvial wells and three bedrock wells) were installed at the 881 Hillside Area to determine the extent, magnitude, and composition of ground water contaminants. Well locations were determined from the Remedial Investigation Plan and modified based on site access as well as geophysical and soil gas survey results. A discussion of each well location is presented below.

Alluvial well 1-87 is located immediately west of Building 881. This well is designed to serve as an upgradient alluvial well, as alluvial ground-water flow in this area is from the north-northwest to the south-southeast.

Wells 2-87 and 3-87BR comprise the well pair located south of SWMUs 106 and 107 and the interceptor ditch in the Remedial Investigation Plan. The actual well pair location was moved north of the interceptor ditch to characterize ground-water conditions closer to potential contaminant sources. Well 2-87 is designed to characterize alluvial ground-water quality immediately downgradient of these areas, and well 3-87BR was completed to investigate bedrock geology and water quality near these potential sources. Soil samples were collected from well 2-87 (BH3-87) before it was completed as an alluvial well.

Wells 4-87 and 5-87BR were to comprise the well pair shown south of SWMU 130 in the Remedial Investigation Plan. Well 4-87 was placed at this location, south of well 9-74 and the volatile organic soil gas plume, to determine the downgradient extent and magnitude of volatile organics emanating from SWMU 119.1. However, bedrock well 5-87BR was moved into SWMU 119.1 to characterize bedrock geology and water quality at the source of contaminants. This well was completed in a zone of fractured claystone approximately three feet thick and an underlying sandstone approximately six feet thick. Both of these zones were water bearing at the time of drilling.

The Remedial Investigation Plan shows a third well pair south of SWMU 119.2 and north of the interceptor ditch. Well 6-87 was originally located south of SWMU 119.2 to characterize alluvial ground-water quality downgradient of that area, and a hole was drilled at that location. However, it was abandoned when no water was encountered in either the surficial materials or the subcropping sandstone. This abandoned hole is designated 6-87A on Plate 4-1. Alluvial well 6-87 was then moved into the swale where wells 1-82 and 2-82 are located. This location was chosen because both wells 1-82 and 2-82 contained water, but no geologic logs or well completion details are available for either well. Thus, well 6-87 was designed to characterize geologic conditions and provide a reliable monitoring well at this location. Bedrock well 7-87BR was moved into SWMU 119.1 and drilled to investigate saturated conditions in weathered claystone on the 881 Hillside. The hole was drilled to a total depth of 51 feet, and sandstone was encountered at 38.6 feet; however, the weathered claystone above the sandstone and the sandstone were dry at this location. Therefore, the hole was plugged with Portland Type I cement and abandoned.

Well 8-87BR was cored through a surface casing set during the 1986 site characterization program. This well was not completed in 1986 because a shallow weathered sandstone was encountered at this location, but it was sealed off by the surface casing which was seated in unweathered bedrock. Well 59-86 was drilled and completed adjacent to the surface casing in the weathered sandstone. The surface casing in hole 60-86 thus not drilled until 1987, when it was renamed 8-87BR. No deeper sandstones were encountered in this hole, but a three foot thick lignite bed was encountered from 85.0 to 88.0 feet. Well 8-87BR was completed in this water bearing lignite.

3.0 DRILLING AND SAMPLING PROCEDURES

Procedures for drilling, sampling, packer testing, and well installation are presented in the CEARP Comprehensive Source and Plume Characterization. Drilling activities followed the procedures set forth in the Plan except for total organic field screening of soil samples and soil sample collection for laboratory chemical analyses. Presented below is discussion of deviations from these procedures.

3.1 VOLATILE ORGANIC FIELD SCREENING PROCEDURES

Total organic field screening of soil samples was performed every five feet in all boreholes except BH12-87 and BH14-87. No field screening was performed in either of these two boreholes. Seventy-five milliliters of soil was placed in an 8 ounce clear glass jar with an equal amount of distilled water. The jar was then shaken and allowed to stand for 30 minutes. The sample jars were labeled with the time, date, borehole number, sample depth and geologist's initials. After 30 minutes, a reading was taken in the headspace of the jar with a PID calibrated to benzene and an OVA calibrated to methane. The headspace readings were recorded in the field notebook.

3.2 SOIL SAMPLES COLLECTION FOR LABORATORY ANALYSIS

Soil samples were collected from cores of each borehole for laboratory analyses. General procedures for soil sample collection are outlined in Section 6 of the CEARP Characterization Plan; however, these procedures were modified slightly upon implementation to simplify the sampling process.

Continuous drive samples were collected from all boreholes from ground surface to total depth. Total depth varied with the depth to bedrock; but all boreholes extended at least three feet into bedrock. The continuous samples were initially screened with a PID, an OVA, and an alpha meter as soon as the sample barrels were opened. Volatile organic field screening samples were then collected every five feet as described above. These two field screening techniques in addition to visual inspection were used to identify suspected waste sources. A waste was defined as any reading above background with the field screening instruments or a visually identified waste.

Both discrete and composite samples were collected from boreholes for laboratory analyses. Figure C-1 presents the sample collection and numbering scheme used for borehole samples. Discrete samples were collected:

1) at a waste source as identified by field screening (designated a "waste sample");

2) at the water table (designated a "water table sample");

3) in alluvium just above the alluvium/bedrock contact (designated a "contact sample"); and,

4) in bedrock three feet below the alluvium/bedrock contact (designated a "bedrock sample").

Waste sample intervals were centered around the waste source. The sample interval extended far enough from the center of the source to collect the appropriate sample volume. If field screening indicated more than one waste source in a borehole, then either the maximum field screening value was sampled or more than one waste was collected, depending on percent core recovery.

Water table samples were collected in boreholes which encountered ground water. The sample interval for these samples extended from the water table downward until the appropriate sample volume was collected.

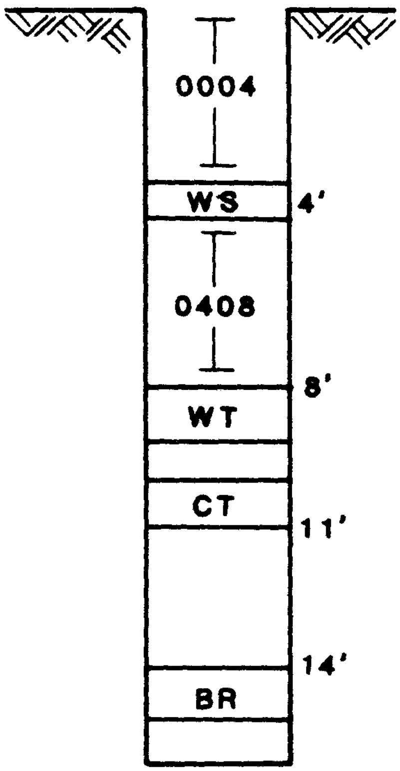
Contact samples were collected from the base of surficial materials at the alluvium/bedrock contact. The sample interval extended from the base of surficial materials upward until the appropriate sample volume was collected.

Bedrock samples were collected from three feet below the alluvium/bedrock contact downward until the appropriate sample volume was collected.

Composite samples were collected from borehole intervals which were not sampled discretely. If no wastes were observed in a borehole, core was composited every ten feet to comprise a composite sample. In boreholes where a waste source was observed, composite samples were collected a maximum of every ten feet above and below the waste. Composite sample intervals varied depending on the amount of available core, the depth of the waste, the depth to water, and the depth to bedrock, as discrete samples were collected before composite samples.

BH0587 0004

Borehole Number   Footage



BH05870004

Composite sample collected from ground surface to observed waste at 4 feet.

BH058704WS

"WS" indicates a waste sample collected based on field screening techniques. A discrete sample is centered around the waste source, and the appropriate volume is collected.

BH05870408

Composite sample collected from waste at 4 feet to water table at 8 feet.

BH058708WT

"WT" indicates water table sample, depth to water table is 8 feet. A discrete sample is collected from the water table down, until appropriate volume is collected.

BH058711CT

"CT" indicates contact sample. Depth to alluvium/bedrock contact is 11 feet. A discrete sample is collected in alluvium from the contact up, until appropriate volume is collected.

BH058714BR

"BR" indicates bedrock sample. A discrete sample is collected from 3 feet below alluvium/bedrock contact, down, until appropriate volume is collected.

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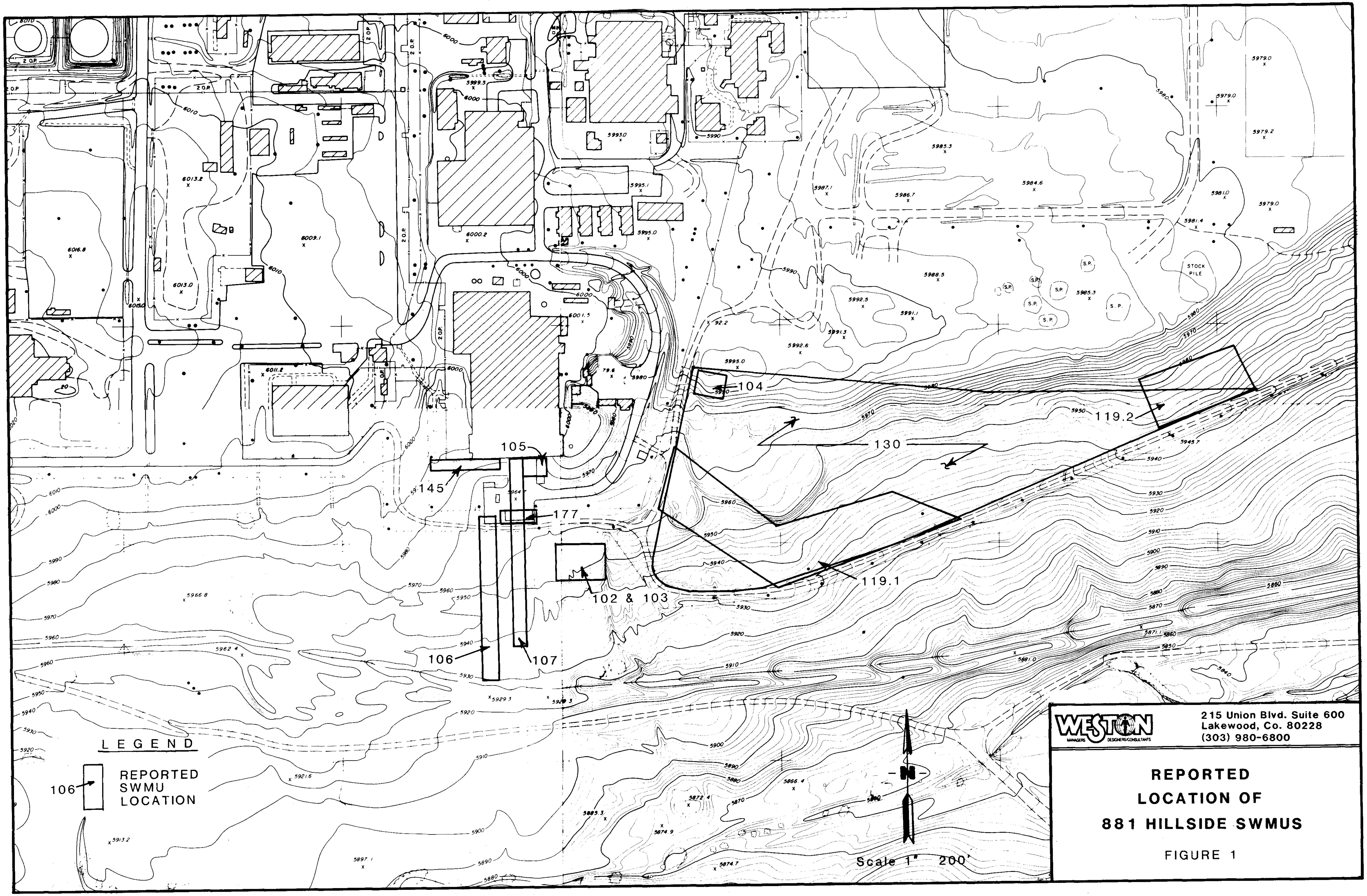
ROCKWELL INTERNATIONAL

Rocky Flats Plant

FIGURE C-1

BOREHOLE SAMPLE COLLECTION AND NUMBERING SCHEME



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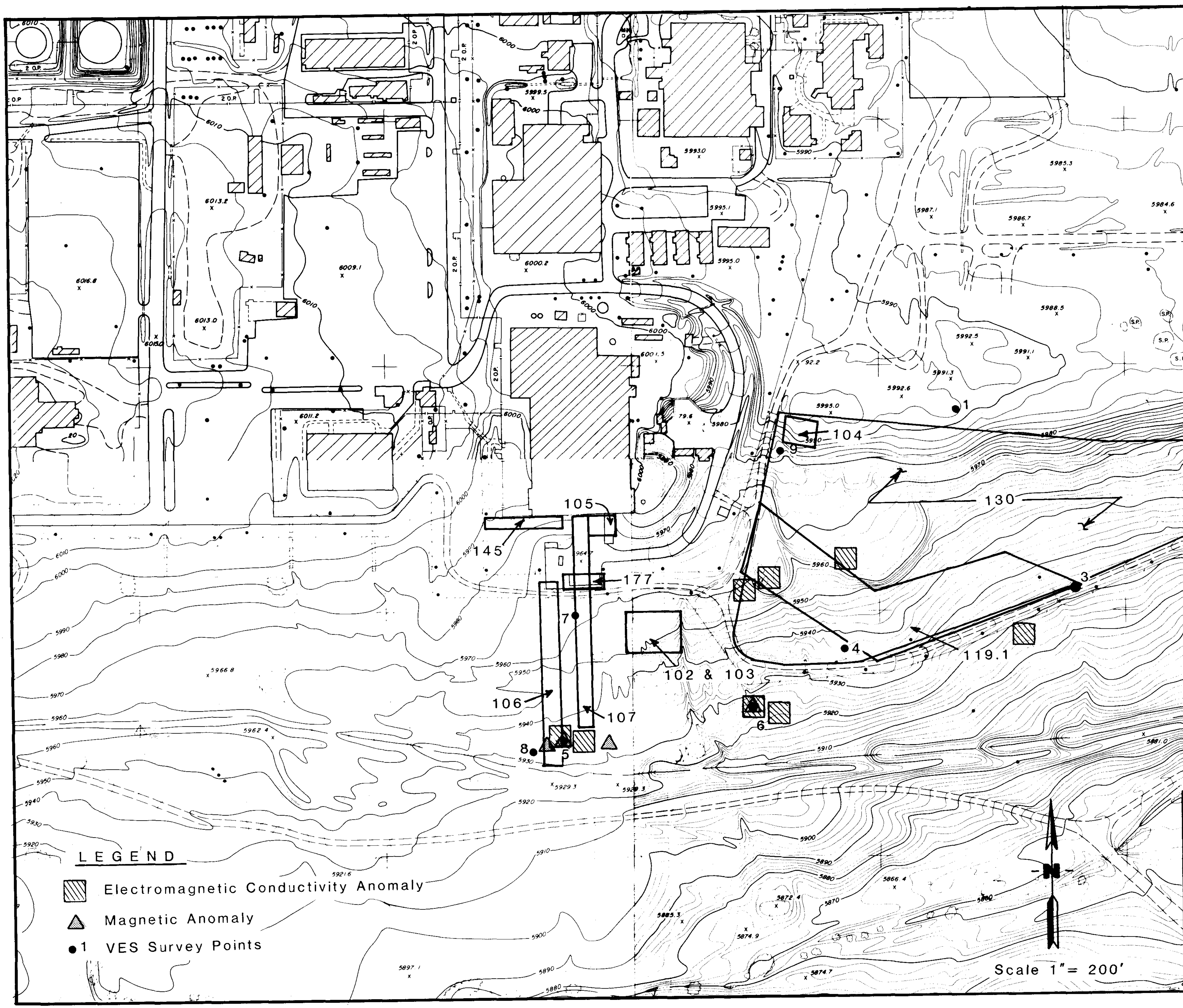
REPORTED LOCATION OF 881 HILLSIDE SWMUS

FIGURE 1



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LOCATION OF GEOPHYSICAL ANOMALIES AND VES SURVEY POINTS

FIGURE 2

6.000

ROCKY FLATS 881 HILLSIDE - EM 31 DATA (PART TWO)

6,000.

RØCKY FLATS 881 HILLSIDE - EM34 HØRIZØNTAL DIPØLE (4/14/87)

6.000+1 ROCKY FLATS 881 HILLSIDE - EM34 VERTICAL DIPOLE (4/14/87)

ROCKY FLATS 881 HILLSIDE - EM34 HORIZONTAL DIPOLE POST (9/19/87)

RØCKY FLATS 881 HILLSIDE - EM 31 DATA